PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference Cal 87221	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/EP 03/14174	International filing date *(day/month/year)* 10.12.2003	Priority date *(day/month/year)* 17.12.2002
International Patent Classification (IPC) or both national classification and IPC F02C9/28		
Applicant NUOVO PIGNONE HOLDING S.p.A. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 17 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
15.06.2004	21.01.2005
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Rau, G Telephone No. +49 89 2399-2914

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP 03/14174

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-32 as originally filed

Claims, Numbers

1-44 received on 07.01.2005 with letter of 05.01.2005

Drawings, Sheets

1/13-13/13 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-44
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-44
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-44
	No:	Claims	

2. Citations and explanations

   see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Document D1=EP 0 728 919 A, which is considered to represent the most relevant state of the art, discloses a corrected parameter control method for a two-shaft gas turbine with corrections related to compressor discharge pressure. The subject-matter of claim 1 differs from document D1 in that the corrections are related to pressure drops in intake pipes, pressure drops in exhaust pipes, variation of the relative humidity of air, and variations of the speed of the low pressure shaft.

   The subject-matter of claim 1 is therefore novel (Article 33(2) PCT).

   Furthermore, said subject-matter is considered to be inventive because none of the available prior art documents or combinations thereof contains any hint that these four corrections should be applied according to the formula given in the characterizing portion of claim 1. It is therefore not obvious for the man skilled in the art to get from the disclosure of document D1 to the combination of features described in independent claim 1, so that the requirements of Article 33 (3) PCT are fulfilled.

2. Dependent claims 2-44 define further embodiments of independent claim 1 which are also new and inventive (Article 33 (2) , (3) PCT).

3. The subject-matter of claims 1-44 is considered to have an industrial application.

CLAIMS

1. Corrected parameter control method for a two-shaft gas turbine, in which ~~characterized in that~~ protection of the said turbine is provided by a first control loop which controls the opening of the fuel valves to keep the temperature Tfire of the gas at the inlet of the first wheel of the said turbine and the fuel-air ration F/A within specified limits; the said control is provided in such a way that the set-point exhaust temperature TX is calculated as the sum of a reference temperature TXbase to which are added corrections relating to a single environmental or operating parameter which differs from the reference parameter characterized in that there are four of the said corrections, the said exhaust temperature TX being expressed by the following formula:

TX = TXbase + DeltaTX DPin + DeltaTX DPout + DeltaTX Hum + DeltaTX PCNLP

where

DeltaTX Dpin is the correction of the temperature TX due to the variation of the pressure drops in intake pipes with respect to a nominal value of 0 mmH2O,

DeltaTX Dpout is the correction of the temperature TX due to the variation of the pressure drops in exhaust pipes with respect to a nominal value of 0 mmH2O,

DeltaTX Hum is the correction of the temperature TX due to the variation of the relative humidity of the air with respect to a nominal value of 60%,

DeltaTX PCNLP is the correction of the temperature TX due to the variation of the speed of the low pressure shaft with respect to a nominal value of 100%.

2. Control method according to Claim 1, characterized in that the said corrections are calculated by computer simulations of the said gas turbine, the said simulations being conducted by specifying the attainment of a maximum of the said temperature Tfire or a maximum of the said fuel-air ratio F/A, for each condition differing from the reference condition.

~~3. Control method according to Claim 1, characterized in that there are four of the said corrections, the said exhaust temperature TX being expressed by the following formula:~~

~~TX = TXbase + DeltaTX_DPin + DeltaTX_DPout + DeltaTX_Hum + DeltaTX_PCNLP~~

~~where~~

~~DeltaTX_Dpin is the correction of the temperature TX due to the variation of the pressure drops in intake pipes with respect to a nominal value of 0 mmH2O,~~

~~DeltaTX_Dpout is the correction of the temperature TX due to the variation of the pressure drops in exhaust pipes with respect to a nominal value of 0 mmH2O,~~

~~DeltaTX_Hum is the correction of the temperature TX due to the variation of the relative humidity of the air with respect to a nominal value of 60%,~~

~~DeltaTX_PCNLP is the correction of the temperature TX due to the variation of the speed of the low pressure shaft with respect to a nominal value of 100%.~~

~~4~~ 3. Control method according to Claim 2, characterized in that the said exhaust temperature TX found by the said simulations is compared with the said reference temperature TXbase, in order to evaluate the said correction terms appropriately, as differences.

~~5~~ 4. Control method according to Claim ~~3~~ 1, characterized in that a maximum exhaust temperature curve is generated for each considered speed of the said low pressure turbine.

~~6~~ 5. Control method according to Claim ~~5~~ 4, characterized in that an equation for evaluating the said current exhaust temperature TX is:

TX = TXbase(PCNLP) + DeltaTX_DPin + DeltaTX_DPout + DeltaTX_Hum

where TXbase(PCNLP) is the reference temperature found for the said specific speed of the said low pressure turbine.

~~7~~ 6. Control method according to Claim ~~6~~ 5, characterized in that there are two values of TXbase(PCNLP), one related to a curve (21) of maximum temperature Tfire and one related to a curve (23) of maximum increase of temperature Trise of the gas in the combustion chamber.

~~8~~ 7. Control method according to Claim ~~7~~ 6, characterized in that the said two maximum values are, respectively,

TX_maxTfire = TXbase_maxTfire(PCNLP,PR) + DeltaTX_DPin + DeltaTX_Dpout + DeltaTX_Hum

TX_maxTrise = TXbase_maxTrise(PCNLP,PR) + DeltaTX_DPin + DeltaTX_Dpout + DeltaTX_Hum,

where a dependence on the compression ratio PR is also expressed.

~~9~~ 8. Control method according to Claim ~~8~~ 7, characterized in that the said temperature curves TXbase_maxTfire and TXbase_maxTrise are provided in the form of two-dimensional tables, with the compression ratio PR and the low pressure turbine speed PCNLP as independent variables.

~~10~~ 9. Control method according to Claim ~~8~~ 7, characterized in that a diagram of the said maximum temperature TX, shown as a function of the compression ratio PR which enables the maximum Tfire to be attained, shows a set of curves (27), each for a specific value of speed PCNLP, the said curve (27) generally having an increasingly negative slope as this speed increases, and being always of the type decreasing with a rise in the compression ratio PR.

~~11~~ 10. Control method according to Claim ~~8~~ 7, characterized in that a diagram of the maximum temperature TX, shown as a function of the compression ratio PR, which enables the maximum Trise to be attained, shows a set of curves (29), each for a specific value of speed PCNLP, the said curve (29) generally having an increasingly negative slope as this speed increases, and being always of the type decreasing with a rise in the compression ratio PR.

~~12~~ 11. Control method according to Claim ~~3~~ 1, characterized in that the said correction DeltaTX_Hum depends on the specific humidity SH and is expressed as a function of a difference DeltaSH, defined as the difference between the actual specific humidity and the specific humidity at a relative humidity of 60% (in the same conditions of temperature and atmospheric pressure), according to the formula:

DeltaSH = SH_current - SH_60%RH.

~~13~~ 12. Control method according to Claim ~~12~~ 11, characterized in that there is a linear correlation (31) between the said DeltaTX_Hum and the said DeltaSH.

~~14~~ 13. Control method according to Claim ~~13~~ 12, characterized in that the said humidity SH_60%RH as a function of atmospheric temperature can be found by interpolating the following values, where the temperature is expressed in degrees Rankine:

SH_60%RH (T=419.67) = 0.000070;

SH_60%RH (T=428.67) = 0.000116;

SH_60%RH (T=437.67) = 0.000188;

SH_60%RH (T=446.67) = 0.000299;

SH_60%RH (T=455.67) = 0.000464;

SH_60%RH (T=464.67) = 0.000707;

SH_60%RH (T=473.67) = 0.001059;

SH_60%RH (T=482.67) = 0.001560;

SH_60%RH (T=491.67) = 0.002263;

SH_60%RH (T=500.67) = 0.003324;

SH_60%RH (T=509.67) = 0.004657;

SH_60%RH (T=518.67) = 0.006367;

SH_60%RH (T=527.67) = 0.008670;

SH_60%RH (T=536.67) = 0.011790;

SH_60%RH (T=545.67) = 0.015966;

SH_60%RH (T=554.67) = 0.021456;

SH_60%RH (T=563.67) = 0.028552;

SH_60%RH (T=572.67) = 0.037585;

SH_60%RH (T=581.67) = 0.048949.

~~15~~ 14. Control method according to Claim ~~3~~ 1, characterized in that the said correction DeltaTX_Dpin is expressed directly as a function of a measured pressure drop DPin.

~~16~~ 15. Control method according to Claim ~~15~~ 14, characterized in that there is a linear correlation (33) between DeltaTX_Dpin and the said Dpin.

~~17~~ 16. Control method according to Claim ~~3~~ 1, characterized in that the said correction DeltaTX_Dpout is expressed directly as a function of a measured pressure drop DPout.

~~18~~ 17. Control method according to Claim ~~17~~ 16, characterized in that there is a linear correlation (35) between the said DeltaTX_Dpout and the said Dpout.

~~19~~ 18. Corrected parameter control method for a two-shaft gas turbine, characterized in that the control of the said turbine at partial loads is provided by a second control loop which controls the opening of a vent valve to keep the temperature rise Trise of the gas in the combustion chamber (and consequently the fuel-air ratio F/A) within specified limits; the said control is provided by means of sets of maps of the exhaust temperature TX as a function of the compression ratio PR, obtained for each operating condition of the said gas turbine.

~~20~~ 19. Control method according to Claim ~~19~~ 18, characterized in that a control curve is defined for each value of atmospheric temperature.

~~21~~ 20. Control method according to Claim ~~20~~ 19, characterized in that there are diagrams showing the

relation between the said temperature TX, for partial loads at a given speed of the low pressure shaft, and the compression ratio PR, each relation curve (37) being associated with a specified value of atmospheric temperature, the said curve (37) generally having higher values as this temperature rises, and being of the type which decreases as the compression ratio PR decreases.

~~22~~ 21. Control method according to Claim ~~21~~ 20, characterized in that the said curves (37) are reduced to a single curve (39), thus eliminating the dependence on the atmospheric temperature.

~~23~~ 22. Control method according to Claim ~~22~~ 21, characterized in that the said curve (39) is obtained by the following mathematical transformation:

$$TTX = TX(518.67/TCD)^{x}$$

where

- TX is the actual exhaust temperature;
- 518.67 is a reference temperature;
- TCD is the exhaust temperature of the compressor, expressed in a unit of measurement compatible with that of the constant;

- X is a nondimensional exponent calculated in such a way as to minimize the mean quadratic deviation between the values of TTX calculated in this way and the interpolation curve (39);

- TTX is the transformed exhaust temperature, in other words the reduced temperature.

~~24~~ 23. Control method according to Claim ~~23~~ 22, characterized in that the said curve (39), when the actual value of PR is known and after the application of the inverse of the said transformation, yields the reference temperature TXbase, from which the set point is calculated for the controller of the said second F/A control loop.

~~25~~ 24. Control method according to Claim ~~24~~ 23, characterized in that the said exhaust temperature TX is calculated by a linear approximation as the sum of the reference temperature TXbase to which are added corrections relating to a single environmental or operating parameter which differs from the reference parameter.

~~26~~ 25. Control method according to Claim ~~25~~ 24, characterized in that there are four of the said

corrections, the said exhaust temperature TX being expressed by the following formula

$$TX = TXbase + DeltaTX\_DPin + DeltaTX\_\_Dpout + DeltaTX\_Hum + DeltaTX\_PCNLP$$

where

TXbase is found by inverting the said transformation, thus: $TXbase = TTX / ((518.67/TCD)^{X})$;

DeltaTX_Dpin is a correction of the temperature TX due to the variation of pressure drops in intake pipes with respect to a nominal value of 0 mmH2O;

DeltaTX_Dpout is a correction of the temperature TX due to the variation of pressure drops in exhaust pipes with respect to a nominal value of 0 mmH2O;

DeltaTX_Hum is a correction of the temperature TX due to the variation of relative humidity of the air with respect to a nominal value of 60%;

DeltaTX_PCNLP is a correction of the temperature TX due to the variation of the low pressure shaft speed with respect to a nominal value of 100%.

~~27~~ 26. Control method according to Claim ~~26~~ 25, characterized in that each correction term is calculated by computer simulations of the gas turbine, the desired F/A ratio being specified, for each

condition differing from the reference condition and at different partial loads, the said exhaust temperature TX found by the said simulations being compared with the reference temperature TXbase, in order to evaluate the correction terms in the appropriate way as differences.

~~28~~ 27. Control method according to Claim ~~27~~ 26, characterized in that a set of curves (41), one for each given value of speed PCNLP, is shown in a diagram of the said maximum temperature TX as a function of the compression ratio PR.

~~29~~ 28. Control method according to Claim ~~28~~ 27, characterized in that an equation for evaluating the current exhaust temperature TX is:

TX = TXbase(PCNLP) + DeltaTX_DPin + DeltaTX_Dpout + DeltaTX_RH

where TXbase(PCNLP) is the reference temperature found for the specific speed of the low pressure turbine.

~~30~~ 29. Control method according to Claims ~~23~~ 22 and ~~29~~ 28, characterized in that the said exponent X is a function of the speed of the low pressure wheel.

~~31~~ 30. Control method according to Claim ~~30~~ 29, characterized in that the exponent X, for intermediate

speeds PCNLP, can be calculated by interpolation of the values of X calculated at the speeds PCNLP considered:

if PCNLP = 105%, X = 0.323

if PCNLP = 100%, X = 0.33225

if PCNLP = 90%, X = 0.34

if PCNLP = 80%, X = 0.34425

if PCNLP = 70%, X = 0.351

if PCNLP = 60%, X = 0.348

if PCNLP = 50%, X = 0.3505.

~~32~~ 31. Control method according to Claim ~~26~~ 25, characterized in that the said correction DeltaTX_RH is calculated by considering:

- three ambient temperatures (very cold day, ISO standard conditions, very hot day);
- three levels of relative humidity (0%, 60%, 100%);
- load characteristics according to a cubic law.

~~33~~ 32. Control method according to Claim ~~32~~ 31, characterized in that nine simulations are conducted, the desired value of F/A being specified, in order to achieve the reference level, the current values of TX then being plotted on a diagram as functions of PR, while a difference between the said diagram and the

base curves yields the said DeltaTX_RH, as expressed in the formula:

DeltaTX_RH = TX - Txbase.

~~34~~ 33. Control method according to Claim ~~33~~ 32, characterized in that the said values of DeltaTX_RH are plotted on the diagram as a function of the difference DeltaSH between the current value of specific humidity SH_current and the specific humidity at RH = 60%, SH_60%RH, which is the reference value, and thus

DeltaSH = SH_current - SH_60%RH.

~~35~~ 34. Control method according to Claim ~~34~~ 33, characterized in that the said diagram shows two straight lines (43 and 45), rising with an increase in DeltaSH, in which a first straight line (43), valid where DeltaSH is less than 0, has a greater slope than the second straight line (45) which is valid where DeltaSH is greater than 0, the two straight lines (43 and 45) passing through a point near the origin of the axes.

~~36~~ 35. Control method according to Claim ~~26~~ 25, characterized in that the said correction DeltaTX_Dpin is expressed directly as a function of the measured pressure drop DPin.

~~37~~ 36. Control method according to Claim ~~36~~ 35, characterized in that the following are considered:

- three ambient temperatures (very cold day, ISO standard conditions, very hot day);
- three pressure drops in the intake (0, 100 and 200 mm of water);
- load characteristics according to a cubic law.

~~38~~ 37. Control method according to Claim ~~37~~ 36, characterized in that nine simulations are conducted, the attainment of the desired value of F/A being specified, in order to achieve the reference level, the current values of TX then being plotted on a diagram as functions of PR, the difference between the said diagram and the base curves yielding the said DeltaTX_Dpin, this being expressed in the formula

DeltaTX_Dpin = TX - Txbase.

~~39~~ 38. Control method according to Claim ~~38~~ 37, characterized in that the said values of DeltaTX_Dpin are linearly correlated (47) with the said Dpin, the said values increasing with a rise in Dpin.

~~40~~ 39. Control method according to Claim ~~26~~ 25, characterized in that the said correction DeltaTX_Dpout

is expressed directly as a function of the measured pressure drop DPout.

~~41~~ 40. Control method according to Claim ~~40~~ 39, characterized in that the following are considered:

- three ambient temperatures (very cold day, ISO standard conditions, very hot day);
- three pressure drops in the exhaust (0, 100 and 200 mm of water);
- load characteristics according to a cubic law.

~~42~~ 41. Control method according to Claim ~~41~~ 40, characterized in that nine simulations are conducted, the attainment of the desired value of F/A being specified, in order to achieve the reference level, the current values of TX then being plotted on a diagram as functions of PR, a difference between the said diagram and the base curves yielding the said DeltaTX_Dpout, as expressed in the formula:

DeltaTX_Dpout = TX - Txbase.

~~43~~ 42. Control method according to Claim ~~42~~ 41, characterized in that the said values of DeltaTX_Dpout are linearly correlated (47) with the said Dpout, the said values increasing with a rise in Dpout.

~~44~~ 43. Control method according to Claims ~~35~~ 34, ~~39~~ 38 and ~~43~~ 42, characterized in that a correlation for calculating the maximum exhaust temperature TX is:

$$TX = TTX(PCNLP, PR) / ((518.67/TCD)^{X(PCNLP)}) +$$

DeltaTX_RH (DeltaSH) +

DeltaTX_Dpin (Dpin) +

DeltaTX_Dpout (Dpout).

~~45~~ 44. Control method according to Claim 1 or ~~19~~ 18, characterized in that the said two-shaft gas turbine is provided with a dry nitrogen oxide (NOx) reduction system.